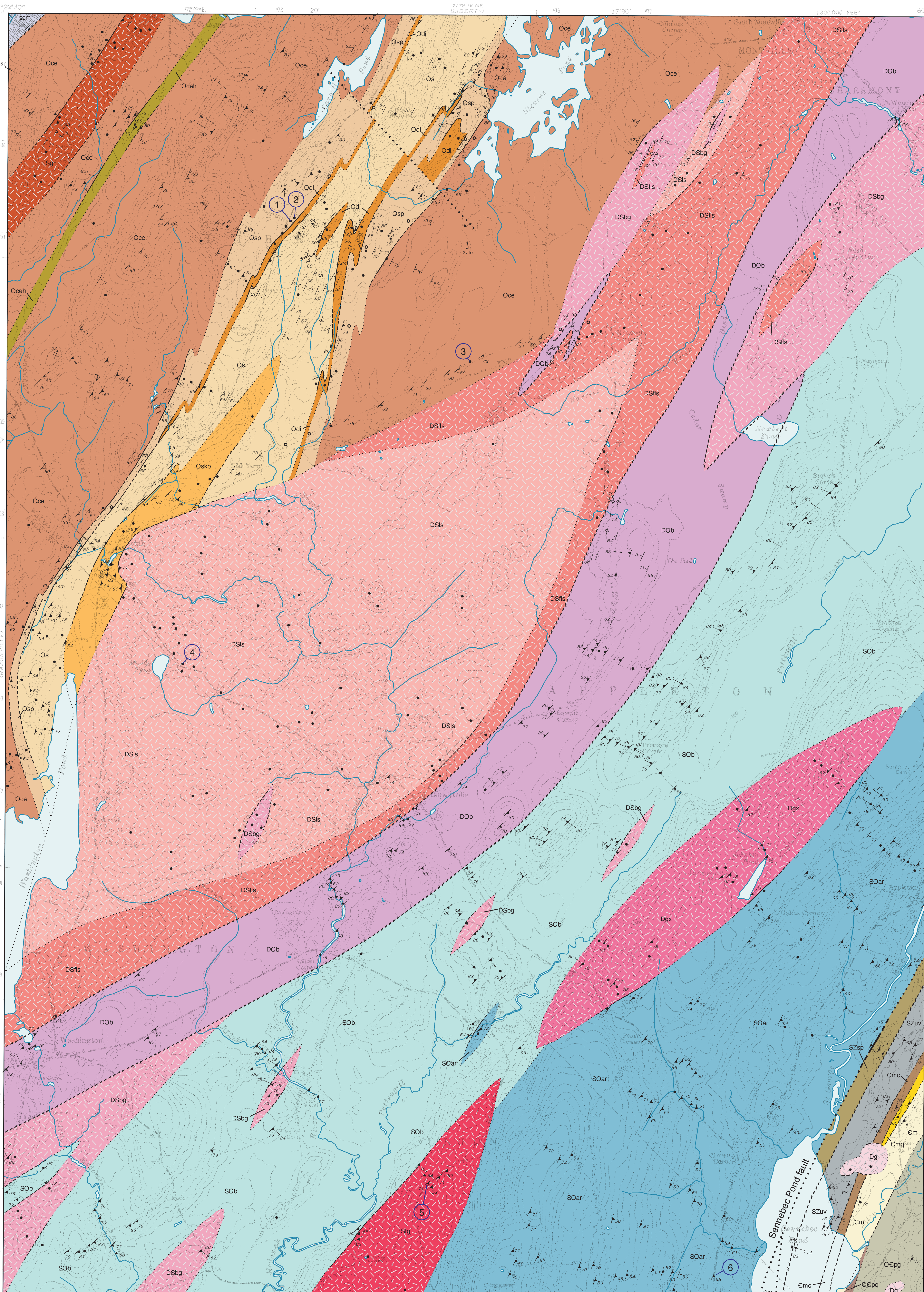
Bedrock Geology



Field work was conducted by D. P. West in 1999 and 2001. Previous reconnaissance mapping at 1:62,500 scale was done by K. A. Pankiwskyj (1976).

Quadrangle Location

SCALE 1 : 24,000

1 MILE — 1000 0 1000 2000 3000 4000 5000 6000 7000 FEET — 1 KILOMETER

CONTOUR INTERVAL 20 FEET

TRUE NORTH

Topographic base from U.S. Geological Survey Washington quadrangle, scale 1:24,000 using standard U.S. Geological Survey topographic map symbols.

The use of industry, firm, or local government names on this map is for location purposes only and does not impute responsibility for any present or potential effects on the natural resources.

Washington Quadrangle, Maine

Bedrock geologic mapping by
David P. West, Jr.

Digital cartography by:
Susan S. Tolman

Robert G. Marvinney
State Geologist

Cartographic design and editing by:
Robert D. Tucker

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Maine Geological Survey
Address: 22 State House Station, Augusta, Maine 04333
Telephone: 207-287-2801 **E-mail:** mgs@maine.gov
Home page: http://www.maine.gov/doc/nrimc/nrimc.htm

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EXPLANATION OF UNITS

STRATIFIED ROCKS

Liberty-Orrington Lithotectonic Belt

Casco Bay Group

Ordovician and Ordovician(?)

Os — **Scarboro Formation.** Medium-gray to purplish-gray, slightly to moderately rusty weathering, medium-grained to coarse-grained, quartz-albite-muscovite-biotite schist. Small (< 2 mm) pink garnets and dark gray to black andalusite porphyroblasts (up to 2.5 cm) are common. At appropriate metamorphic grade, sillimanite, staurolite, and cordierite are locally present. Compositional layering is generally thin and discontinuous, with little evidence of bedding preserved. Discontinuous, complexly folded quartz segregations (0.5 to 5 cm thick) are ubiquitous. Rare layers (up to several meters thick) of greenish gray, coarse-grained, hornblende-plagioclase ± garnet gneiss are present.

Oskb — **Kingdom Bog Member.** Medium gray to purplish gray, rusty to non-rusty weathering, fine-grained to medium-grained biotite granofels with minor interlayered calc-silicate granofels and rusty weathering biotite schist. The rocks are well layered (0.5 to 5 cm thick), and generally weather to a slabby appearance. This unit was defined by Pankiwskyj (1976).

Odi — **Diamond Island Formation.** Dark gray to black, rusty weathering, sulfidic, graphite-rich quartzite and quartz-muscovite schist. Rare pink coticule layers up to a meter thick are present. Other sedimentary features have not been observed.

Osp — **Spring Point Formation.** Greenish-gray to dark gray, non-rusty to slightly rusty weathering, medium to fine grained, biotite-hornblende-plagioclase schist, gneiss and granofels; and light gray, medium-grained to fine-grained, biotite-quartz-plagioclase gneiss and granofels. The two rock types are in places interlayered, but typically they are found separately at the outcrop scale. These rocks are interpreted to represent metamorphosed volcanics. A U-Pb zircon age of 469 ± 3 Ma from location 1 has been interpreted to represent the age of eruption (Tucker and others, 2001). A $^{40}Ar/^{39}Ar$ hornblende age of 381 ± 3 Ma from location 2 is interpreted to reflect the time of cooling following Devonian amphibolite facies metamorphism (West and others, 1995).

Oce — **Cape Elizabeth Formation.** Light gray to silver-gray, non-rusty weathering, medium-grained, quartz-plagioclase-muscovite-biotite ± garnet ± sillimanite schist interlayered with light-gray, non-rusty weathering, fine-grained quartz-plagioclase micaeous granofels. Schistose layers typically lack aluminosilicate minerals. Contacts between schist and granofels are generally sharp, with layering on the order of 1-15 cm thick. Minor calc-silicate granofels and hornblende amphibolite layers up to 30 cm thick are present. $^{40}Ar/^{39}Ar$ cooling ages of 380 ± 4 Ma for hornblende, and 357 ± 3 Ma for muscovite (West and others, 1995) were determined at locality 3 on the map.

Oceh — **Hibberts Corner member.** Light gray to medium gray, fine-grained, non-rusty weathering, quartz-plagioclase-amphibole-biotite ± garnet granofels and gneiss interlayered with medium gray, fine-grained quartz-plagioclase-biotite granofels. Layers are less than 6 cm thick. Commonly weathers to a slabby appearance. Unit defined by Pankiwskyj (1976).

Fredericton Lithotectonic Belt

Silurian-Ordovician (?)

SOb — **Bucksport Formation.** Purplish-gray, non-rusty weathering, fine-grained, quartz-plagioclase-biotite granofels interlayered with greenish-gray, non-rusty weathering, fine-grained, plagioclase-quartz-actinolite-diopside granofels. Layers range in thickness from 2 to 12 cm. Rare layers of rusty-weathering, medium-grained biotite schist are present. The unit is characterized by the distinct and sharp compositional layering of biotite granofels and calc-silicate granofels which when deeply weathered forms distinctive ribbed outcrop surfaces.

SOar — **Appleton Ridge Formation.** Light gray to silver-gray, non-rusty to slightly rusty weathering, medium to coarse-grained, quartz-plagioclase-muscovite-biotite-garnet ± staurolite ± andalusite ± sillimanite schist interlayered with light gray, non-rusty weathering, fine-grained quartz-plagioclase-muscovite-biotite granofels. Layers range in thickness from 1 to 50 cm, with granofels layers noticeably thinner than schistose layers in most exposures. Contacts between layers are generally sharp, although graded beds are present locally. In the schistose layers, porphyroblasts include small pink garnet grains (< 2 mm), deep red-brown generally untwinned staurolite (up to 3 cm), and andalusite ranging from inconspicuous poikiloblasts to coarse-grained chiastolite (up to 10 cm). In some rocks, andalusite has been replaced by aggregates of coarse-grained muscovite ± staurolite ± chloritoid in pseudomorphs. An $^{40}Ar/^{39}Ar$ cooling age of 344 ± 3 Ma was determined from locality 6 (West and others, 1995.

St. Croix Lithotectonic Belt

Ordovician-Cambrian (?)

Penobscot Formation

O€pg — **Gushee Member.** Dark gray to black, rusty weathering, fine-grained, plagioclase-hornblende amphibolite, locally containing relict pillow structures. The unit also contains subordinate medium gray, rusty weathering, fine-grained to coarse-grained anthophyllite gneiss. This unit is poorly exposed in the southeastern corner of the Washington quadrangle, but it is well exposed in the adjacent quadrangles to the south and east (Union and Searsmont 7.5' quadrangles).

O€pq — **Quartzite.** Rusty weathering, dark bluish-gray, graphitic quartzite. Occasional coarse flakes of biotite. Inferred to underlie south edge of map, from exposures in the adjacent Union quadrangle.

Cambrian (?)

€m — **Megunticook Formation.** Light gray, slightly rusty weathering, medium-grained quartz-biotite-muscovite schist characterized by small pink garnets (< 1 mm) and coarse-grained white mica in pseudomorphs after andalusite (up to 2 cm in length). Compositional layering is generally inconspicuous, and discontinuous when discernible. Original bedding features are obscure. This unit is on strike with part of the Jam Brook Formation mapped by Bickel (1976) in the adjacent Searsmont 7.5' quadrangle.

€mq — **Quartzite member.** Light gray to white, non-rusty weathering, generally massive and clean quartzite. Relatively minor amounts of light gray, slightly rusty weathering quartz-mica schist containing small pink garnets and muscovite pseudomorphs after andalusite. This unit is on strike with the quartzite member of the Jam Brook Formation mapped by Bickel (1976) in the Searsmont 7.5' quadrangle.

€mc — **Calc-silicate member.** This unit contains several thin rock types, but calc-silicate rocks are most common. Medium gray to purple gray, slightly rusty weathering, fine-grained biotite granofels is interlayered with greenish gray, fine-grained calc-silicate granofels. Layering ranges from 1 to 6 cm thick. Subordinate rock types include light gray, slightly rusty

Rocks of Uncertain Lithotectonic Belt

Devonian-Ordovician(?)

DOb — **Burkettville Complex.** Rocks within this complex are penetratively deformed and nearly all contain steeply dipping mylonitic foliations. Several different rock types can be found within the complex, although nearly all exposures can be grouped into one of three types: (1) Mylonitic granite gneiss. Light gray to white, medium-grained to pegmatitic, strongly foliated, locally lineated, biotite granite gneiss and garnet-bearing, muscovite-biotite granite gneiss. (2) Mylonitic granitic gneiss interlayered with porphyroclastic biotite gneiss and minor calc-silicate gneiss. Dark gray to purplish-gray, fine-grained to medium-grained, quartz-plagioclase-biotite gneiss and minor greenish-gray calc-silicate gneiss interlayered with the mylonitic granite gneiss described above. The biotite gneiss characteristically contains plagioclase porphyroclasts up to 2 cm in diameter. Layering ranges from 2 cm to well over a meter thick. (3) Mylonitic granitic gneiss interlayered with porphyroclastic mica schist. Medium gray to purplish-gray, medium-grained to coarse-grained, plagioclase-quartz-biotite-muscovite-garnet ± prismatic sillimanite schist interlayered with mylonitic granitic gneiss as described in (1) above.

The mylonitic granitic gneisses (1 above) have been previously mapped as part of the Haskell Hill Granite Gneiss to the southwest and North Searsmont Granite Gneiss to the northeast (Osberg and others, 1985). Tucker and others (2001) report U-Pb zircon ages of 408 ± 5 Ma and 389 ± 2 Ma, respectively, for these bodies. The porphyroclastic biotite gneisses, calc-silicate rocks and schists (2 and 3 above) are on strike with portions of the Passagassawakeag Formation mapped by Bickel (1976) in the Searsmont and Morrill 7 ½' quadrangles to the east and northeast.

Structures and textures within the complex indicate the rocks have been subjected to severe penetrative ductile deformation. The current complex distribution of rock types is a result of tectonic processes superimposed on country rocks intruded by Devonian granitic magma (the North Searsmont granite gneiss). The complex is tentatively interpreted to have formed in late Devonian time during the final juxtapositioning of the Fredericton Belt with rocks of the Casco Bay Belt (including the Lincoln alkali feldspar syenite) in late Devonian time. Both macroscopic and microscopic kinematic indicators are primarily symmetrical, although some asymmetric indicators are present, most of which indicate a dextral sense of shear. Thus the kinematics associated with the juxtapositioning of these belts are indeterminate.

Silurian-Precambrian Z (?)

SZuv — **Unnamed metavolcanic rocks.** Greenish-gray, slightly rusty weathering, fine to coarse-grained, hornblende-plagioclase amphibolite. Megacrysts of amphibole and plagioclase, locally up to 8 mm in diameter, appear to be relict phenocrysts; coarse-grained, elliptical calcite "knots" may represent relict amygdules. Weathered pits up to 8 cm in length, elongate parallel to the foliation, are also present locally. The rock is generally massive, but contains characteristic anastamosing fracture patterns. Relatively minor amounts of light gray to buff colored, non-rusty weathering, fine-grained quartz-plagioclase granofels are interlayered with the amphibolite. The age of this unit is uncertain, and its relationship to adjacent units is unclear. It is on strike with part of the calc-silicate member of the Jam Brook Formation mapped by Bickel (1976) in the Searsmont 7.5' quadrangle.

SZsp — **Sennebec Pond fault complex.** A large variety of metasedimentary and metavolcanic rocks in layers too thin to be mapped separately (generally < 5 meters thick each). This map unit is approximately 200 meters in width, immediately east of the Sennebec Pond fault. At least 10 different rock types can be distinguished in outcrop, including: gray to purplish-gray, massive quartzite; purple-gray, very fine-grained, thinly laminated (< 0.5 cm), quartz-plagioclase-biotite granofels interlayered with light green calc-silicate granofels; light gray, slightly rusty weathering, quartz-mica schist with white mica in pseudomorphs after andalusite; dark gray to black, slightly rusty weathering, hornblende-plagioclase amphibolite; white to buff colored, very fine-grained, quartz-plagioclase granofels with plagioclase grains that might be relict phenocrysts; and light gray, medium-grained to coarse-grained, calcite marble. Where exposed, contacts between rock types are sharp.

The available bedrock exposure is insufficient to allow mapping of these individual thin units along strike to establish their extent. Some of them may correlate with parts of the Jam Brook sequence mapped by Bickel (1976) on strike in the Searsmont 7.5' quadrangle. Considering the wide range of rock types exposed in thin belts over such a short distance, it seems likely that these units have been structurally thinned and tectonically interleaved. Folds, foliation, truncated and dismembered layering, and boudinage are ubiquitous in these units, suggesting that they have been sheared and tectonically stretched. No simple kinematic model can account for all the structural features present, due to complicated overprinting metamorphism and polydeformation. The diverse assemblage of rocks in this map unit is interpreted to have been amalgamated during relative motion of the St. Croix and Fredericton Lithotectonic Belts along the Sennebec Pond fault in Late Silurian to Middle Devonian time. The original depositional ages of the rocks are unknown.

HIGHLY DEFORMED ROCKS

scm — **Sandhill Corner mylonite.** Dark gray, fine to medium grained, mylonite and ultramylonite characterized by porphyroclasts of feldspar (up to 1 cm) and muscovite set in a dark, fine-grained to aphanitic matrix. Within this zone, layers of light gray mica schist and micaeous granofels typical of rock types in the Cape Elizabeth Formation are common. This mylonite zone was originally recognized and mapped by Pankiwskyj (1976) and is part of the regionally extensive Norumbega fault system. $^{40}Ar/^{39}Ar$ muscovite ages from this mylonite zone have been interpreted to reflect a late Carboniferous to early Permian age for the mylonite formation (West and Lux, 1993). The Sandhill Corner mylonite zone is poorly exposed in the extreme northwestern corner of this quadrangle, but it is well exposed in the Razorville 7 ½' quadrangle to the west (West and Peterman, 2004).

EXPLANATION OF SYMBOLS

- Outcrop of mapped unit
- Float presumed to represent underlying bedrock
- Bedding (upright)
- Foliation or compositional layering (inclined, vertical)
- Foliation (inclined, vertical)
- Axial plane of minor fold
- Hinge of isoclinal fold
- Hinge of asymmetric fold, dextral asymmetry
- Hinge of kink fold
- Lineation
- Joint (inclined, vertical)
- (4) Sample location for radiometric age listed in unit descriptions

EXPLANATION OF LINES

- Lithologic contact (well located, approximately located, poorly located or inferred).
- High angle fault (well located, approximately located, poorly located or inferred).
- Structural domain boundary.

INTRUSIVE ROCKS

Devonian(?)

Dg — **Tourmaline-muscovite granite.** Light gray, coarse-grained to pegmatitic, non-foliated to weakly foliated, tourmaline-bearing, muscovite granite. These rocks may be related to the Devonian Waldoboro Pluton Complex (Sidle, 1991), exposed 13 km south of the Washington quadrangle.

Dgx — **Foliated biotite-muscovite granite with xenoliths.** Light gray, coarse-grained to pegmatitic, moderately to strongly foliated, biotite-muscovite±sillimanite±garnet granite with abundant metasedimentary xenoliths up to 5 meters across. Xenoliths of light gray sillimanite schist (Appleton Ridge Formation) are abundant near the eastern margin, whereas xenoliths of biotite and calc-silicate gneiss (Bucksport Formation) are abundant near the western margin.

Devonian-Silurian (?)

DSbg — **Foliated biotite granite.** Medium gray, medium-grained to coarse-grained, moderately to strongly foliated, locally lineated, biotite granite, locally containing garnet or muscovite. These granitic rocks were likely intruded in late Silurian to early Devonian time and subsequently strongly deformed in the middle to late Devonian.

Devonian-Silurian

DSls — **Porphyritic shonkinite of the Lincoln Sill (of Trefethen, 1937).** Dark gray to purplish-gray, non-foliated to weakly foliated, porphyritic, actinolite-clinopyroxene-biotite shonkinite (alkali feldspar syenite). Characterized by purplish-gray alkali feldspar megacrysts up to 6 cm in length set in a matrix of fine-grained to medium-grained alkali feldspar, actinolite, clinopyroxene and biotite. Local alignment of alkali feldspar phenocrysts is interpreted to reflect original igneous processes. Pankiwskyj (1976) used the name shonkinite for this rock due to its high content of ferromagnesian minerals. A U-Pb zircon age of 418 ± 1 Ma from location 4 has been interpreted to represent the original crystallization age of the intrusion (Tucker and others, 2001).

DSfls — **Foliated, porphyritic shonkinite of the Lincoln Sill (of Trefethen, 1937).** Dark gray to purplish-gray, moderately to strongly foliated, porphyritic, sphene-bearing, actinolite-biotite shonkinite (alkali feldspar syenite). Matrix minerals (actinolite and biotite) are foliated, and purplish-gray to white alkali feldspar megacrysts are strongly aligned within the plane of foliation, and locally lineated. Locally the grain size of the megacrysts has been significantly reduced by deformation. Kinematic indicators along the immediate southeastern boundary suggest this deformation is due to dextral strike-slip shear most likely in middle to late Devonian time.

Silurian

Stg — **North Union tonalite gneiss.** Light to medium gray, medium-grained, strongly foliated and lineated biotite-quartz-plagioclase gneiss. A U-Pb zircon age of 422 ± 2 Ma is interpreted to represent the original crystallization of the tonalite pluton, while a U-Pb monazite age of 386 ± 1 Ma likely reflects a later episode of metamorphism in the gneiss (Tucker and others, 2001). Both ages are from location 5 on the map.

Sgn — **Lake St George granite gneiss.** Light gray, medium-grained, strongly foliated and locally lineated, biotite-quartz-plagioclase-alkali feldspar gneiss. A U-Pb zircon age of 422 ± 2 Ma from the Liberty 7.5' quadrangle is interpreted to represent the original crystallization of the granite pluton (Tucker and others, 2001).

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